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THE PHYSIOGRAPHIC ECOLOGY OF CHICAGO AND VICINITY; A STUDY OF THE ORIGIN, DEVELOPMENT, AND CLASSIFICATION OF PLANT SOCIETIES.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY XXIV.

HENRY CHANDLER COWLES.

[*Concluded from p. 108.*]

2. THE POND-SWAMP-PRAIRIE SERIES.

A. *The pond.*—There are all gradations between rapid streams and completely undrained ponds, and corresponding with these various gradations are characteristic plant species. It will be convenient to subdivide the series under discussion into two parts, the first dealing with undrained ponds and swamps, the second with half-drained ponds and swamps.

No two floras can be more unlike in species or in adaptations than are the typical brookside and swamp floras. Though each type may be called hydrophytic, so far as the water is concerned, the vegetation is really hydrophilous in the first case but pronouncedly xerophilous in the second. Peat bogs which may be taken as the type of undrained swamps have a remarkable assemblage of xerophytic adaptations, such as leathery or hairy leaves, and special structures for water absorption. Schimper[23] believes

[23] SCHIMPER: Pflanzengeographie, p. 18.

that these structures are due to the difficult absorption in peaty soil, the humus acids and the lack of oxygen being detrimental to normal root activities. For similar reasons the normal soil activities of bacteria and fungi are lessened, and as a result of this relative lack of decay great quantities of peat accumulate. All of these peculiarities of peat bogs may be referred to the lack of drainage, since the stagnant conditions prevent oxidation and the removal of the humus acids. The lack of drainage is of course due to topographic conditions. Peat bogs and undrained lakes, therefore, are features of a young topography, since several agencies combine to cause their rapid destruction. Rivers may work back and tap the undrained lakes or inlets may fill them up. Probably the most important agent in the death of undrained lakes, however, is the vegetation, as will be seen later. The great abundance of lakes and ponds in the young glaciated regions as compared with older regions to the south is a striking proof of their short life.

In the immediate neighborhood of Chicago typical peat bogs are scarce. They find their best development in the depressions of the dune region, where they may be called abundant. Wherever a sag between two dunes is low enough to retain moisture for the greater part of the season, the conditions favor the development of an undrained swamp flora. If the depression is so low that the water level outcrops throughout the year, then there is an undrained pond or lake. The first flora in this latter case consists of plants that are able to exist with little or no change in the water of the pond except through rain and evaporation. Among these plants the alga Chara takes a prominent place. The water lilies (Nymphaea and Nuphar) are an exceedingly important constituent of this first vegetation, as is also Utricularia, which is represented by several species. The above species, together with others, play a great part in filling up lakes, since their remains accumulate with almost no decay. Chara in particular is a soil former of great importance. The rapidity with which these filling processes are carried on is striking; in pools of known age among the rubbish heaps of

Jackson park the author has noticed accumulations of Chara peat amounting to one or two inches per year.

Spring vs. Pond

B. *The undrained swamp.*— It is obvious that the processes outlined in the preceding paragraph must eventuate in the death of the lake or pond involved and its replacement by a marsh, entirely apart from ordinary erosive activities. Indeed, as has been stated, these activities are relatively unimportant here; this fact is shown by the absence of ordinary sediments from most peat beds. As the aquatics make the pond shallower and shallower they make it more and more unfit for themselves and fit for their successors, viz., those plants which grow along pond margins. Among the first plants of this type are various sedges (Carex), also the bulrush (*Scirpus lacustris*), though this latter species is more characteristic of the half-drained margins than of those under discussion here. Other marginal plants of our peat bogs are *Menyanthes trifoliata* and *Potentilla palustris*.

The vegetation that follows may be called typical of peat bogs. The dominant plants are usually shrubs, especially the leather leaf (*Cassandra calyculata*); this plant may be so abundant as to give tone to the landscape. *Fig. 19* shows some Cassandra islands in a sedge swamp. It is clear that the islands represent places where in the original lake the water was shallow. The present remnant of the lake is shown at the left. Not only have the sedge zones advanced upon it from all sides, but centers of sedge growth appear also in shallow places in the lake itself. Just as the sedge zone encroaches upon the lake, when conditions become favorable, so the Cassandra zone advances on the sedges. Again a tree zone advances on the shrubs, as will be seen farther on. The zonal arrangement of plant societies that has just been seen is a feature of most peat bogs, and is due to the symmetry of lake and bog conditions. It will be observed that along the lake margin the zones advance toward a common center, while on the islands the advance is from a center. Eventually, of course, the marginal and island zones will merge.

Besides Cassandra many other plants are commonly found

in the shrub zone. Other shrubs are the swamp blueberry (*Vaccinium corymbosum*), the cranberry (*Vaccinium macrocarpon*), the dwarf birch (*Betula pumila*), the alder (*Alnus incana*), the hoary willow (*Salix candida*), and the poison sumach (*Rhus venenata*). Characteristic herbs, especially in the open places, are the pitcher plant (*Sarracenia purpurea*), the sundew (*Drosera rotundifolia*),

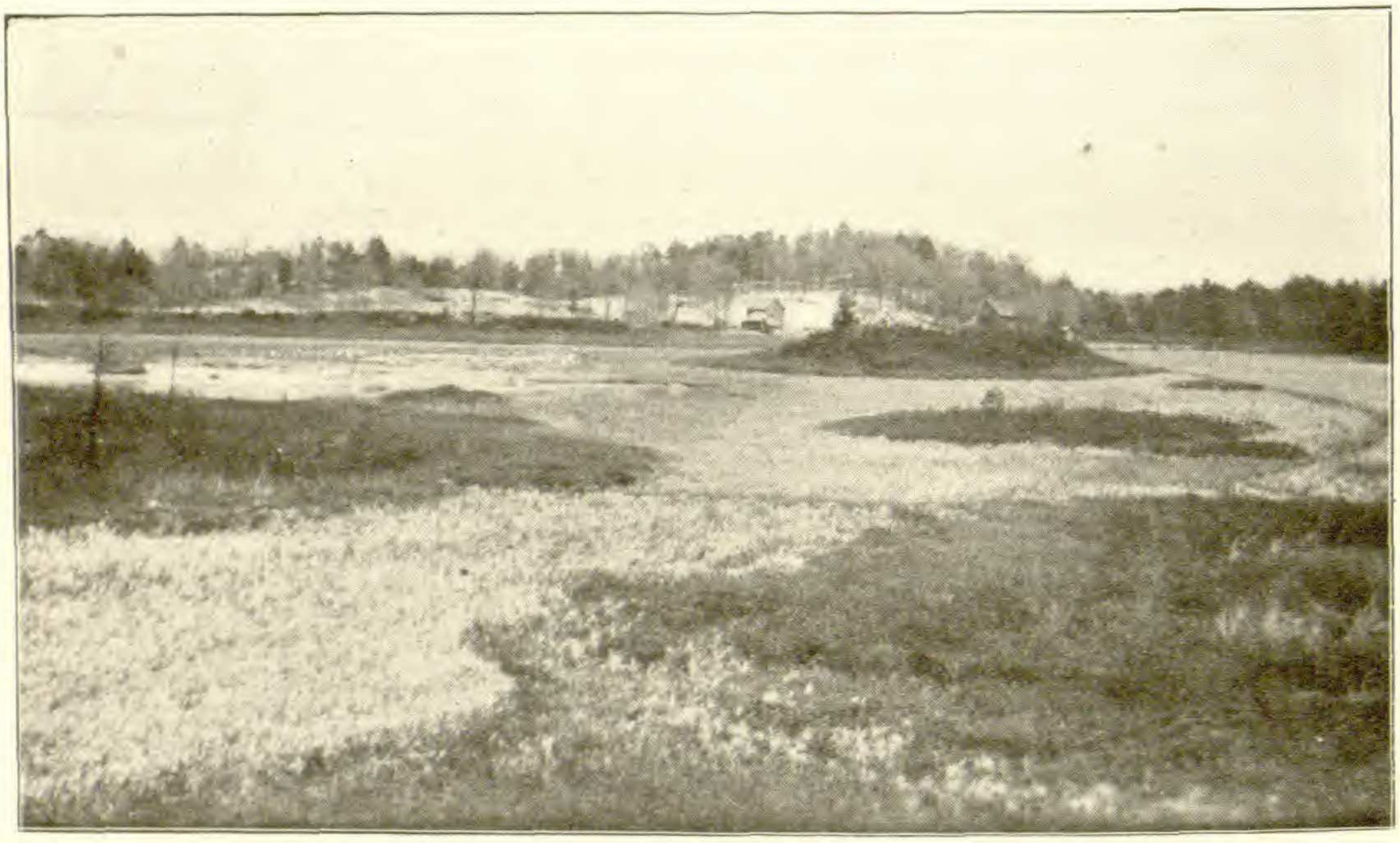

FIG. 19.—Typical peat bog in a depression between established dunes at Miller. Relict of the original pond at the left. Sedges (light-colored vegetation) are encroaching on the lake, while shrubs, mainly Cassandra, are encroaching on the sedges. Cassandra islands toward the right. Advance of conifers on Cassandra (seen in its beginnings on the islands) shown at the extreme right.

various orchids, as *Calopogon pulchellus*, Pogonia, and Cypripedium; sedges, as Eriophorum and Dulichium; *Woodwardia Virginica*, and *Elodes campanulata*. One of the most typical plants of these places is the peat moss, Sphagnum.

The flora just mentioned has many interesting features which are well known and may be passed over briefly. The highly xerophytic character of this plant society has already been noticed, and the reasons for it briefly given. The xerophytic structures are well illustrated in the leathery leaves of Cassandra and the absorption and storage adaptations of Sphagnum.

Many bogs of this type are very spongy and unstable, whence the name quaking bogs; this feature is due to the rapid growth of the vegetation and the absence of ordinary inorganic soils for a considerable depth. The similarity of the peat bog vegetation throughout the northern hemisphere is one of its most striking features. Not only the adaptations but the species themselves

FIG. 20.—Tamarack swamp in an undrained portion of the Calumet flood plain at Miller. Peat bog herbs and shrubs in the foreground.

are similar over vast areas; the conditions are unique and the flora also. None of our plant societies, not even the lakeward dune slopes, have such a pronounced northern flora as do the peat bogs. No contrast could be more striking than that between the southern vegetation of the flood plains and the northern flora of the bogs.

Fig. 19 shows that a coniferous vegetation, now represented by but two or three small trees at the centers of the islands, is to follow the Cassandra. Such an advance of conifers on Cassandra is shown in the background at the right. The most typical conifer in such cases is the tamarack (*Larix Americana*); with this the arbor vitae (*Thuya occidentalis*) is sometimes found.

Larix and Thuya swamps reach but an imperfect development in our region and little need be said about them. The shade in these forest swamps is so dense that bare patches of soil are often seen. The vegetation consists largely of shade plants, among which may be mentioned Mnium and other similar mosses, *Coptis trifolia*, *Cornus Canadensis*, *Viola blanda*, and Impatiens. The tamaracks appear to be succeeded by the pines (*Pinus Strobus* or *P. Banksiana*), and they in turn by oaks, as the soil becomes drier and better drained, and thus more adapted to deciduous trees. *Fig. 20* shows a tamarack swamp near Miller, Ind.

Not all peat bogs have a history like the above. Just as some flood plains are forested and others not, so some peat bogs grow up to shrubs and trees, while others are dominated, for a long time at least, by herbs and grasses. *Fig. 21* shows a swamp of this character. Bulrushes are seen to be encroaching upon the water lily vegetation, while back of the bulrushes, instead of Cassandra, is a zone with sedges and grasses and scattered willows. Among the species, other than sedges and grasses in a plant society like this are *Viola sagittata* and *V. lanceolata*, *Potentilla Anserina*, *Fragaria Virginiana*, *Parnassia Caroliniana*, *Sabbatia angularis*, *Gentiana crinita*, *Gerardia purpurea*, *Castilleia coccinea*, *Aletris farinosa*, *Iris versicolor*, *Sisyrinchium angustifolium*, *Hypoxys erecta*, *Xyris flexuosa*, *Triglochin maritima*. The shrubs in such places are chiefly *Salix glaucophylla*, *Cornus stolonifera*, *Potentilla fruticosa*, *Hypericum Kalmianum*. The conditions that determine this type of bog, as contrasted with the Cassandra type, are not clear. The soil is hard, compact, shallow, and usually sandy; it may be that this type develops in shallow depressions, while the type with spongy, quaking ground develops in deeper depressions. This second type much more closely resembles the half-drained swamps in its flora than does the Cassandra type, although so far as drainage is concerned it agrees with the Cassandra bogs.

There is yet a third type of swamp which still more closely resembles the half-drained swamp in its flora. It is found along the edge of the Calumet valley near Dune park, also at West

Pullman. In this case the soil is rather deep and rich, in which respects there is agreement with the first type rather than the second. Grasses and sedges, but of a more luxuriant type, dominate here also, and with them are found such plants as *Cephalanthus occidentalis*, *Aspidium Thelypteris*, *Onoclea sensibilis*, *Saxifraga Pennsylvanica*, *Caltha palustris*, *Viola blanda*, *Polygala sanguinea*.

FIG. 21.— Shallow, undrained swamp (peat bog) at Dune park. In the foreground the relict of the original pond, with water lilies; then in order, encroaching zones of bulrushes, sedges, willows, and pines. The oaks in the background are on an established dune, and are not encroaching on the swampy soil.

Sphagnum occasionally occurs here, as it never does in the second type. Here again there is doubt as to the determining conditions, but it may be that things can be explained by the difference in the drainage. The ultimate fate of the second and third swamp types is not known. The relative absence of trees and shrubs is certainly natural and in no wise due to man.

Possibly local prairies will be the final type, or it may be that the forest will come in. *Fig. 21*, which shows pines encroaching upon the grassy areas, favors the latter view. So do some of the facts seen in the Calumet valley.

All of the peat bog types have a characteristic marginal flora, *i. e.*, the vegetation at the margin of the original lake is essentially alike in all cases. These plants, as well as those of

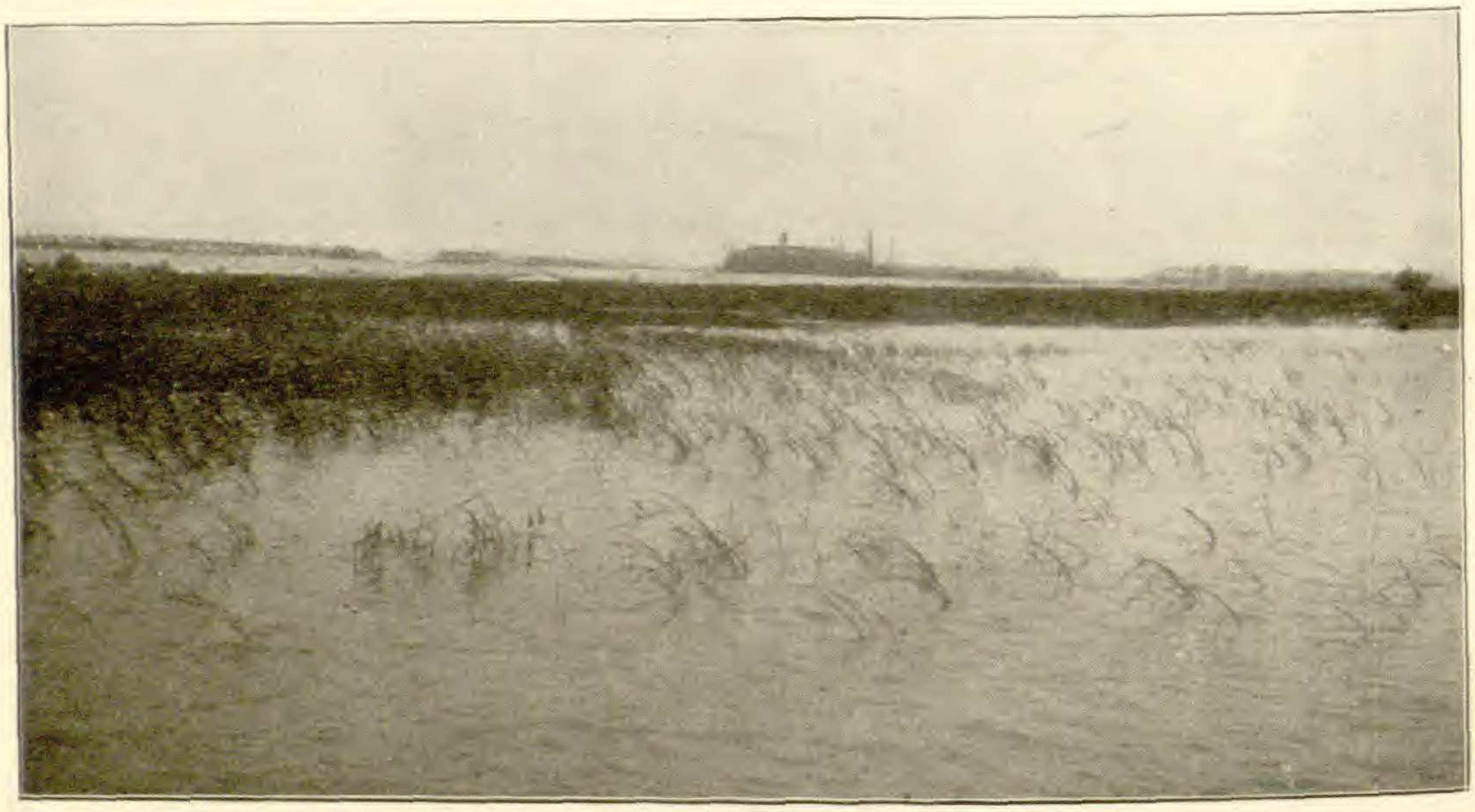

FIG. 22.—Encroachment of bulrushes on Calumet lake, showing how plants may destroy lakes.

Cassandra bogs, are the same over wide areas. The most common members of the bog margin flora are the sour gum (*Nyssa sylvatica*), the aspen (*Populus tremuloides*), *Ilex verticillata*, *Pyrus arbutifolia* (including var. *melanocarpa*), *Spiraea salicifolia* and *S. tomentosa*, *Rubus hispidus*, *Gaultheria procumbens*, *Osmunda cinnamomea*, *O. Claytoniana*, *O. regalis*, *Betula papyrifera*, and *Polytrichum commune*. This vegetation originates outside the swamp, and may be regarded as xerophytic; however, it often encroaches upon the swamp as the latter develops. At Thornton there is a dead swamp which is now almost entirely occupied by this xerophytic bog margin flora, only a few of the original swamp plants now remaining. Near Morgan park is a

bog margin flora without a bog; a shallow trench has been dug and in this trench there have appeared various peat bog plants, *e. g.*, Sphagnum. These considerations show that bog margin floras, though associated with most bogs, are not necessarily genetically connected with them.

A word may be said about undrained swamps among the active dunes. The conditions here, of course, are far more severe than in ordinary peat bogs and only a few species are

FIG. 23.— Pond at Waukegan almost destroyed by bulrushes.

able to endure in such a habitat. The most typical herb is *Juncus Balticus littoralis*. Seedlings of the cottonwood, as well as the long-leaved and glaucous willows, germinate in these wet depressions. Reference will be made to these plants in connection with the dunes.

In the morainic portions of our territory there are few if any peat bogs as described above, although they are usually more typical of moraines than of other topographic areas. On account of the clay soil which characterizes the morainic uplands there are many patches of swampy woods throughout the district. Shallow depressions of this type in sandy soil would not have a swamp developed. Morainic forest swamps are characterized by several trees, viz.: the bur oak, swamp white oak, and scarlet

oak (*Quercus macrocarpa*, *Q. bicolor*, and *Q. coccinea*), the red maple (*Acer rubrum*), the elm (*Ulmus Americana*), and the ash (*Fraxinus Americana*). Other species are *Cephalanthus occidentalis*, *Salix discolor*, *Ribes floridum*, *Cardamine rhomboidea purpurea*, *Ranunculus septentrionalis*. This vegetation is ultimately supplanted by the mesophytic forest. A vegetation allied with that

FIG. 24.—Typical grass prairie near Pullman. This prairie has been reclaimed naturally from Lake Calumet, and has passed through bulrush and sedge stages.

of swamps is the amphibious ditch flora with such plants as *Nasturtium palustre*, *Penthorum sedoides*, *Proserpinaca palustris*, *Ludwigia palustris*, *Polygonum Hydropiper*, etc.

Calumet lake and Grand Calumet river may be taken as types of half-drained waters. We have here conditions that are midway between those of peat bogs and those of ordinary rivers. The vegetation is subject neither to the currents of the rivers nor to the stagnant conditions of the peaty lakes, and hence the luxuriance of the flora is far greater than in either of the other instances. The aquatic vegetation is rich both in species and

individuals. Here is to be found a great wealth of alga vegetation, including such forms as Cladophora, Spirogyra, Oedogonium, Hydrodictyon. Among the floating plants are Riccia, Ricciocarpus, Spirodela, Lemna, and Wolffia. There are also a large number of attached plants, including many species of Potamogeton, *Ranunculus aquatilis*, Brasenia, Nelumbo, Myriophyllum, Ceratophyllum, Elodea, Vallisneria, and Naias. This rank growth of vegetation fills the lake up rapidly, since the currents are not sufficient to carry off the plant remains. There is a rapid advance of marginal plants upon the lake, a phenomenon that is shown in *fig. 22*, where the scattered bulrushes (*Scirpus lacustris*) are seen to be soon followed by a dense bulrush society. With or soon after the bulrushes are a number of marginal plants, especially *Typha latifolia*, *Pontederia cordata*, *Sparganium eurycarpum*, *Sagittaria variabilis* and *S. heterophylla*, *Zizania aquatica*, *Phragmites communis*, *Acorus Calamus*, and *Eriophorum cyperinum*. *Fig. 23* shows a stage in which a lake has been all but destroyed by a rank bulrush vegetation.

C. *The prairie.*—Sedges encroach rapidly upon the bulrushes as the new soil becomes raised more and more above the lake, and grasses in turn encroach upon the sedges, forming a prairie. *Fig. 24* shows an expanse of grassy prairie which has developed through these successive stages from Calumet lake. Skokie marsh and Hog marsh are undergoing transformations of this character also. Sometimes with the prairie grasses are a number of coarse xerophytic herbs, largely composites (*Silphium laciniatum*, *S. terebinthinaceum*, *S. integrifolium*, Lepachys, *Solidago rigida*, Aster, Liatris), with some legumes (*Amorpha canescens*, Petalostemon, Melilotus, Baptisia), Eryngium, Dodecatheon, Phlox, *Allium cernuum*. A Silphium (compass plant) prairie is shown in *fig. 25*. The prairies of our area are in the basin of the glacial Lake Chicago, and hence all may be referred to a lake or swamp origin, exactly as prairies are developing from Calumet lake today. This explanation of the prairie, an undoubted explanation for the cases in hand, must not be applied to the great climatic prairies farther west. Whether

the Chicago prairies will ever become forested is a question not easily answered. There are signs of it in some places, as at Stony island, but this topic needs more detailed treatment than can be given here.

The processes outlined in this section are rapid. The mesophytic prairie or forest develops from the lake or marsh, while the region as a whole still retains a young topography. Thus

FIG. 25.—Prairie at Pullman in which the compass plant (Silphium) grows with the grasses. This prairie is much older and drier than that shown in *fig. 24*.

this mesophytic assemblage, like that of the ravine slope, is bound to pass away, though its life tenure is much longer. Sooner or later river action will enter; there will be developed ravines, xerophytic bluffs, and ultimately flood plains, again with a mesophytic flora. A broad survey then shows a rapid development to a somewhat prolonged temporary climax, and finally after ravine and bluff vicissitudes there appears the true and more enduring climax of the mesophytic flood plain.

3. THE UPLAND SERIES.

A. *The rock hill.*—While all of a land area is eventually worked over by stream activities and can thus be referred to the

river series, other activities are at work in a young topography. The swamp series which has just been discussed is one illustration. So also there are hills which are not due to erosive processes, but to other causes, notably in our region morainic

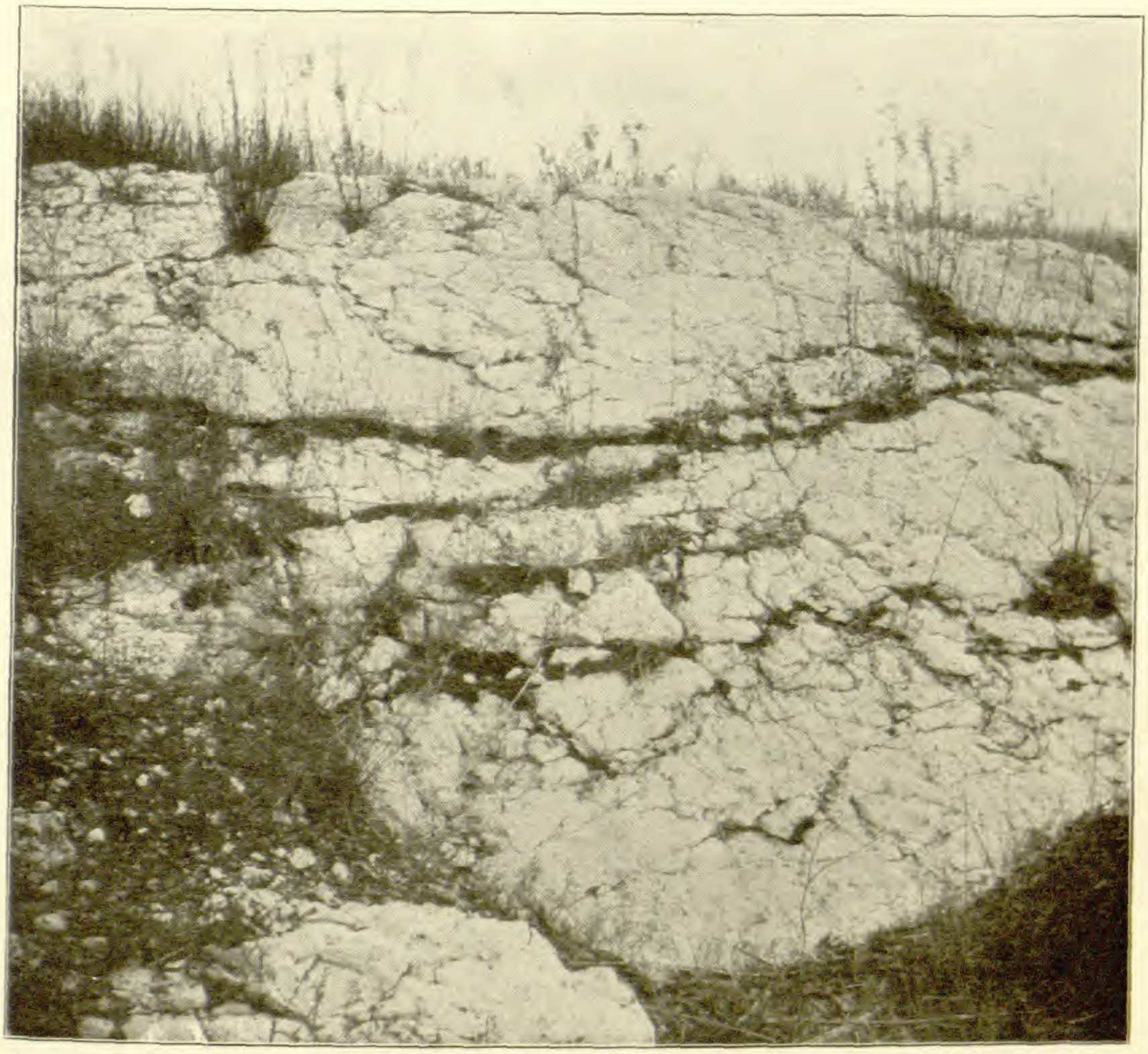

FIG. 26.—Slope of limestone ledge at Stony island, showing mosses and higher plants establishing themselves in the crevices.

hills and sand hills. There are rock hills also which are not connected with the present erosion cycle. All of these hill types have their peculiar vegetation features and must be discussed apart from river activities, since they have an interesting history before they are attacked by stream erosion.

We may speak first of rock hills, which in the vicinity of

Chicago are quite rare and consist entirely of dolomitic Niagara (Silurian) limestone. Not only are hills of this limestone quite rare, but surface outcrops of any kind are uncommon because of the heavy drift. Hence the rock vegetation of the Chicago area is not very important. Perhaps the most interesting outcrop is at Stony island, where it is quite easy to trace the various stages in the development of the vegetation. This rock, like most limestone, is subject to chemical as well as mechanical erosion, but is much more resistant than most limestones on account of its strongly dolomitic character. The first vegetation that gets a foothold is composed of lichens, but the lichen flora appears to be rather sparse, perhaps because of the chemical nature of the rock, since lichens are commonly supposed to shun calcareous soils. The relative poverty of lichens may be due, however, to the easy solution of the surface rock layers and the consequent difficulty in retaining a foothold. The limestone is considerably jointed and fractured and there is in consequence a rich crevice vegetation, composed of several mosses, especially Ceratodon and Bryum, and also various grasses. *Fig. 26* shows a vegetation of this nature, and among the other crevice plants is an abundance of *Solidago nemoralis*. Other species growing in the crevices or on the first soil which is formed on the rock face are *Potentilla arguta*, *Verbascum Thapsus*, *Heuchera hispida*, *Poa compressa*, etc. At Thornton there is a rock outcrop which gradually recedes from the surface, and it is possible to tell by the vegetation where the rock surface dips considerably under the surface of the soil. Where the soil is shallow the dominant plant is *Poa compressa*, but as the soil layer deepens it becomes gradually replaced by *Poa pratensis*. Similarly at Stony island crevices can be distinguished in a covered horizontal rock surface by a sudden change from the xerophytic plants of the shallow soil, that hides most of the rock, to the mesophytic plants of the deeper soil which lies over the crevices.

Through rock decay and the accumulation of organic matter a considerable soil comes to be developed where there was at

first an outcrop of bare rock. The opportunity for a shrubby vegetation eventually arrives, especially in the crevices. *Fig. 27* shows such a vegetation getting a foothold. Among the shrubs in such places are the chokecherry (*Prunus Virginiana*),

FIG. 27.—Limestone ledge at Stony island, showing vegetation farther advanced than in *fig. 26*. The crevice shrubs here are chokecherries (*Prunus Virginiana*).

ninebark (*Physocarpus opulifolius*), poison ivy (*Rhus Toxicodendron*), *Rosa humilis*, sumach (*Rhus typhina*), hop tree (*Ptelea trifoliata*), wild crab (*Pyrus coronaria*). Still later the way is open for a tree vegetation, at first xerophytic, but ultimately mesophytic, as the author has frequently observed in the Alleghanies. There can be no doubt but that a temporary mesophytic climax can be reached even on rock hills, though the probability of this

is much greater where the hill is composed of limestone than in the case of sandstone or granite.

B. *The clay hill.*— Morainic hills are common in the Chicago region and almost without exception they are covered with a mesophytic forest, in which the dominant trees are usually the

FIG. 28.—Typical upland clay (morainic) forest at Beverly hills. The dominant trees here are red oaks (*Quercus rubra*), though a white oak (*Q. alba*) is shown at the extreme right.

white oak (*Quercus alba*), the red oak (*Quercus rubra*), and the shell-bark hickory (*Carya alba*). This is easily the dominant forest type of the Chicago region, and is remarkably characteristic of morainic areas. The soil in all cases is a glacial clay or till, heterogeneous in composition, but rich in food salts. Of all our plant society life histories these are about the most difficult to unravel and it is due to the favorable conditions under which they have developed. After the continental glacier left this region for the last time, it was doubtless on these low

morainic hills that the first mesophytic forests were developed. And they have been developed for so long that almost no traces of their history are left behind; we have only the completed product, the mesophytic forest.

Where these mesophytic forests are disturbed we may perhaps get some notion of what took place in the first postglacial centuries. On the clay banks along the drainage canal and also on recent river bluffs, one may follow in rapid succession a series of plant societies leading to the forest. There is here no pronounced lichen or moss stage as on rock hills, but the first vegetation consists of xerophytic annuals and perennial herbs. Xerophytic shrubs, especially Salix and Populus, soon appear. It is not long before there is an extensive thicket formation with an herbaceous undergrowth. Humus accumulates with great rapidity and we soon have almost a mesophytic vegetation in which the dominant thicket species are likely to be the aspen (*Populus tremuloides*), wild crab (*Pyrus coronaria*), red haw (*Crataegus punctata, C. coccinea*, etc.). Such a thicket is the immediate forerunner of the oak-hickory type of mesophytic forest. When a forest of oak and hickory is cut down or destroyed by fire it returns after a comparatively short interval, but the first stages in the clearing are thicket stages much like those just described. Of course it takes much longer to develop a forest from naked clay soil than from a forest land that has been cleared. Whether the stages that led up to the first postglacial forests are such as have been described is very doubtful. It is much more likely that the first forests were of slow growth and were coniferous in character, such as are found farther north. *Fig. 28* shows a typical morainic hill forest of the above type. Here the dominant tree is the red oak; a white oak is seen at the right.

Among the shrubs of these morainic forests there may be mentioned, apart from the crabs and haws, the hazel (*Corylus Americana*), and various species of Viburnum. Many herbaceous plants are found, among which are Podophyllum, Claytonia, various species of Aster, Trillium, *Geranium maculatum, Viola*

pubescens, *Anemone nemorosa*, etc. Sometimes the bur oak (*Quercus macrocarpa*) is the dominant tree in these morainic forests, though in such cases the habitat is usually more moist or else the drainage is less perfect. A bur oak forest is shown in *Fig. 29*. The transition from this type to the morainic swamp forests, already mentioned, is an easy one, and bur oaks are often

FIG. 29.—Typical forest of low morainic clay soil, made up chiefly of bur oak (*Quercus macrocarpa*).

found with the swamp white oak and other species characteristic of such places.

In spite of the abundance of the type of morainic forest described above, it is scarcely probable that it is anything more than a very slowly passing forest stage. The fact that in all directions from Chicago the ultimate forest type on morainic uplands is not the oak-hickory but the maple-beech forest leads us to expect that here. This latter type seems to be of a higher order in all respects. It is found in richer soil where the humus content is very great. Seedlings of the beech or maple can easily grow in the relatively light oak forest, whereas oaks cannot grow in the denser shade of the maple or beech. Furthermore,

oak forests have been seen with a pronounced undergrowth of beech. It would seem that one of the chief factors in determining the order of succession of forests is the light need of the various tree species, the members of the culminating forest type being those whose seedlings can grow in the densest forest shade. There are evidences that the oak forests about Chicago are being succeeded by the beech or maple. The best instance of this which the author has seen is on the low moraines along the Desplaines river west of Deerfield. The sugar maple (*Acer saccharinum*) has already been mentioned as a character plant of the temporary mesophytic forests of ravines. Here we see it in the more permanent forest of the morainic hills. The beech (*Fagus ferruginea*) is much rarer than the sugar maple, though it is a rather important constituent of the mesophytic forests about Chesterton. Why the beech-maple forest has lagged so far behind in the region about Chicago is a question not yet settled. If these forests elsewhere have had an oak stage it indicates that the development here is very slow.

Though the forests just described, whether of the oak-hickory or the maple-beech type, are of a high degree of permanence, it can be seen that this permanence is but relative. Sooner or later stream action will enter these districts and base leveling processes will begin on a more rapid scale. But for these activities the lowering of hills would be very slow indeed, so slow as hardly to interfere at any point with a luxuriant development of the vegetation. The destruction of these morainic forests by stream erosion is well shown near the shore north of Evanston and also along Thorn creek. *Fig. 18* shows a morainic island in a flood plain, the sole remnant of an extensive stretch of upland mesophytic forest. We must therefore regard upland forests as temporary also, though they endure for a much longer time than do the temporary mesophytic forests of the ravines.

C. *The sand hill.*—A third type of upland is found in the sand hills, but since most of these in our district are of dune origin, their treatment will be deferred until later.

B. The coastal group.

I. THE LAKE BLUFF SERIES.

The plant societies that have been discussed hitherto may be found in many if not in most inland districts. The societies that follow, on the other hand, are best worked out only in connection with the coasts of oceans or great lakes. Theoretically a bluff may be composed of any kind of rock or soil, but those of our area are composed of morainic clays, and the life histories that follow will not hold good in other conditions. It may be noted here that there is a short stretch of rocky shore with lithophytic algae at Cheltenham, but there is nothing that in any way approaches a rock cliff.

Wherever a sea or lake erodes rather than deposits, there is commonly developed a sea cliff of greater or less dimensions. The material which is thus gathered may be deposited elsewhere in the form of beaches and later the wind may take up the sands from the beach and form dunes. The Chicago area gives splendid examples of these two types of sea activity; to the north of the city is an eroding coast line with its bluffs, and to the south and southeast is a depositing coast with extensive areas of beach and dune.

The lake bluffs at Glencoe give an excellent opportunity for the study of the life history of a sea-cliff vegetation. There can be almost no other habitat in our climate which imposes such severe conditions upon vegetation as an eroding clay bluff. The only possible rival in this regard is a shifting dune, and even here the dune possesses some points of advantage so far as the establishment of vegetation is concerned. In the first place, the conditions as to exposure are almost identical with those of a dune: the heat of midday and of summer and the cold of night and winter are extremely pronounced; the intensity of the light and the exposure to wind make the conditions still more severe. In other words the only plants that can grow on these lake bluffs, at least in the earlier stages, are pronounced xerophytes. Again the character of the soil is unfavorable, for while the clay is wet in the autumn, winter, and spring, it dries out in the summer and

becomes almost as hard as rock. In the heart of summer the conditions for vegetation are no better on the hard dry slopes of a clay bluff than on the hot, dry sands of a dune. Finally as to instability: it is doubtless the constant shifting of the sand which in the last analysis accounts for most of the poverty of the dune vegetation. It is similar on clay bluffs, for when the

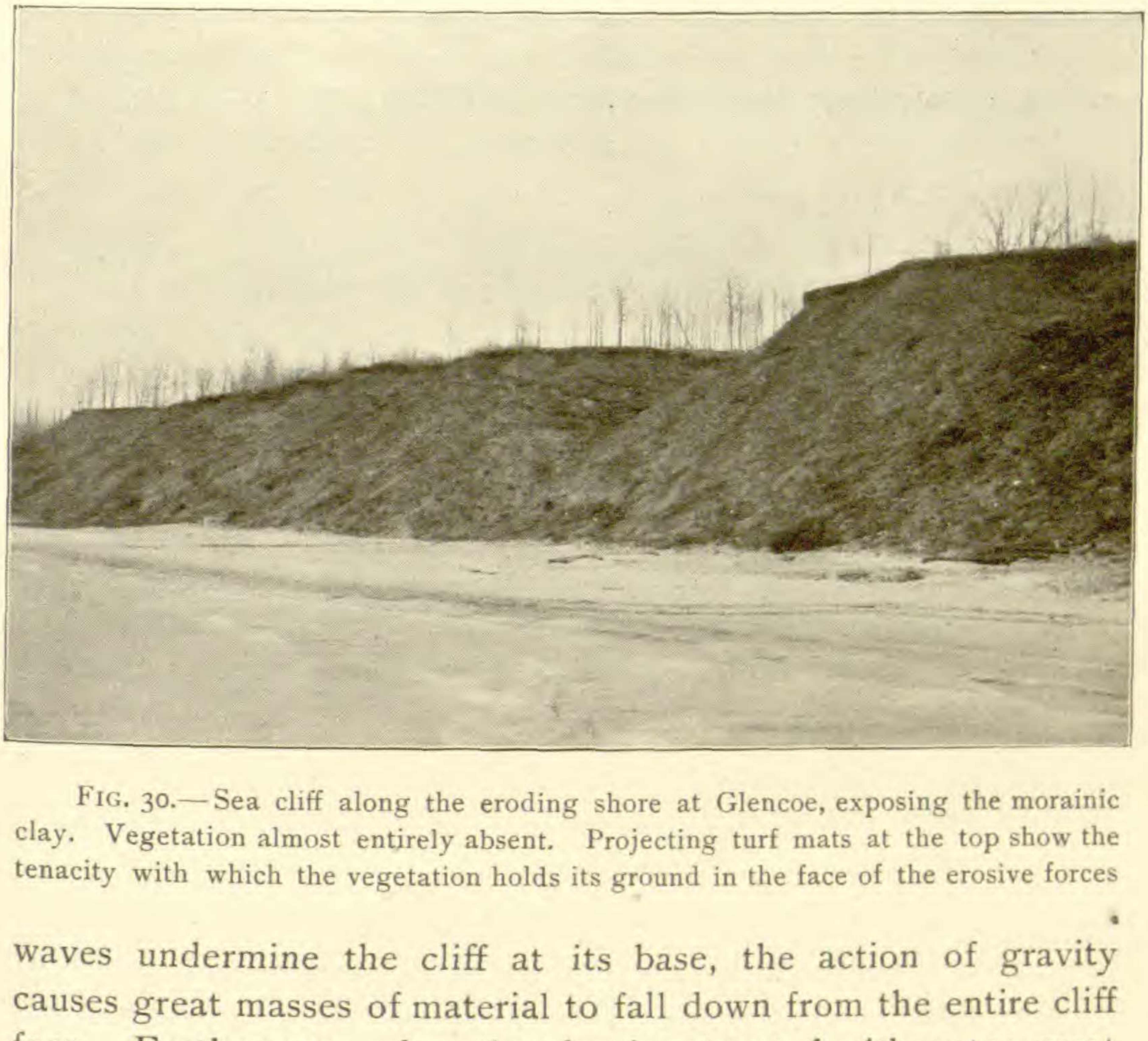

FIG. 30.—Sea cliff along the eroding shore at Glencoe, exposing the morainic clay. Vegetation almost entirely absent. Projecting turf mats at the top show the tenacity with which the vegetation holds its ground in the face of the erosive forces

waves undermine the cliff at its base, the action of gravity causes great masses of material to fall down from the entire cliff face. Furthermore, when the clay is saturated with water, great portions of the cliff face slide down, entirely apart from the action of the sea or lake. At no time, then, is an eroding bluff any more stable than a naked dune.

It becomes evident from a survey of the bluff conditions that all vegetation is impossible so long as active erosion by the lake continues. Not only this, but vegetation at the top of the bluff is soon destroyed. *Fig. 30* shows a naked cliff of this

character ; at the top there can be seen overhanging turf, giving evidence both of the destructive action of the lake and also of the tenacity with which a grass mat holds its place in the presence of adverse conditions. Near the center of *fig. 31* may be seen a white oak which was almost overthrown by the erosive activities, but which has been preserved through the cessation of erosion at this point. The gully shown near the center of *fig. 30* is seen in closer view in *fig. 1;* the absence of vegetation, save that which has slid down from above, is very striking.

If for any reason the lake activities at the base of the cliff are stopped, an opportunity is offered for the development of vegetation. At Glencoe the cliff erosion has been checked to some extent by artificial means, and one can see various phases of cliff life within a small area. When the erosion at the base of the bluff ceases, conditions become much more stable, though landslide action may still occur. In time the slope gradient becomes so low that the cliff soil is essentially stable ; when this time arises vegetation develops with great rapidity in spite of the xerophytic conditions which are still as pronounced as before. It is very obvious, therefore, that it is the instability of the eroding cliff and not its xerophytic character which accounts for the absence of plant life.

The first vegetation is commonly made up of xerophytic herbs, both annual and perennial. Among these are the sweet clover (*Melilotus alba*), various annual weeds, various species of aster, especially *A. laevis, Equisetum hyemale,* various grasses, etc. Soon there develops a xerophytic thicket vegetation, such as is shown in *fig. 31*. This may be called the shrub stage of the captured cliff, and among the dominant species are the juniper and cedar (*Juniperus communis* and *J. Virginiana*), *Salix glaucophylla*, the osier dogwood (*Cornus stolonifera*), *Shepherdia Canadensis*, various sumachs (*Rhus typhina* and *R. glabra*). The following tree stage is dominated by various poplars (*Populus tremuloides, P. grandidentata, P. monilifera*), the hop hornbeam (*Ostrya Virginica*), the white pine (*Pinus Strobus*), the red cedar (*Juniperus Virginiana*), and some of the oaks (probably *Quercus*

rubra and *Q. coccinea tinctoria*). *Fig. 32* shows a tree-clad cliff in which most of the above trees are to be found.

Whether a mesophytic forest would develop on a lake bluff is something of a question. It seems likely that semi-xerophytic trees will dominate there for a long time to come on

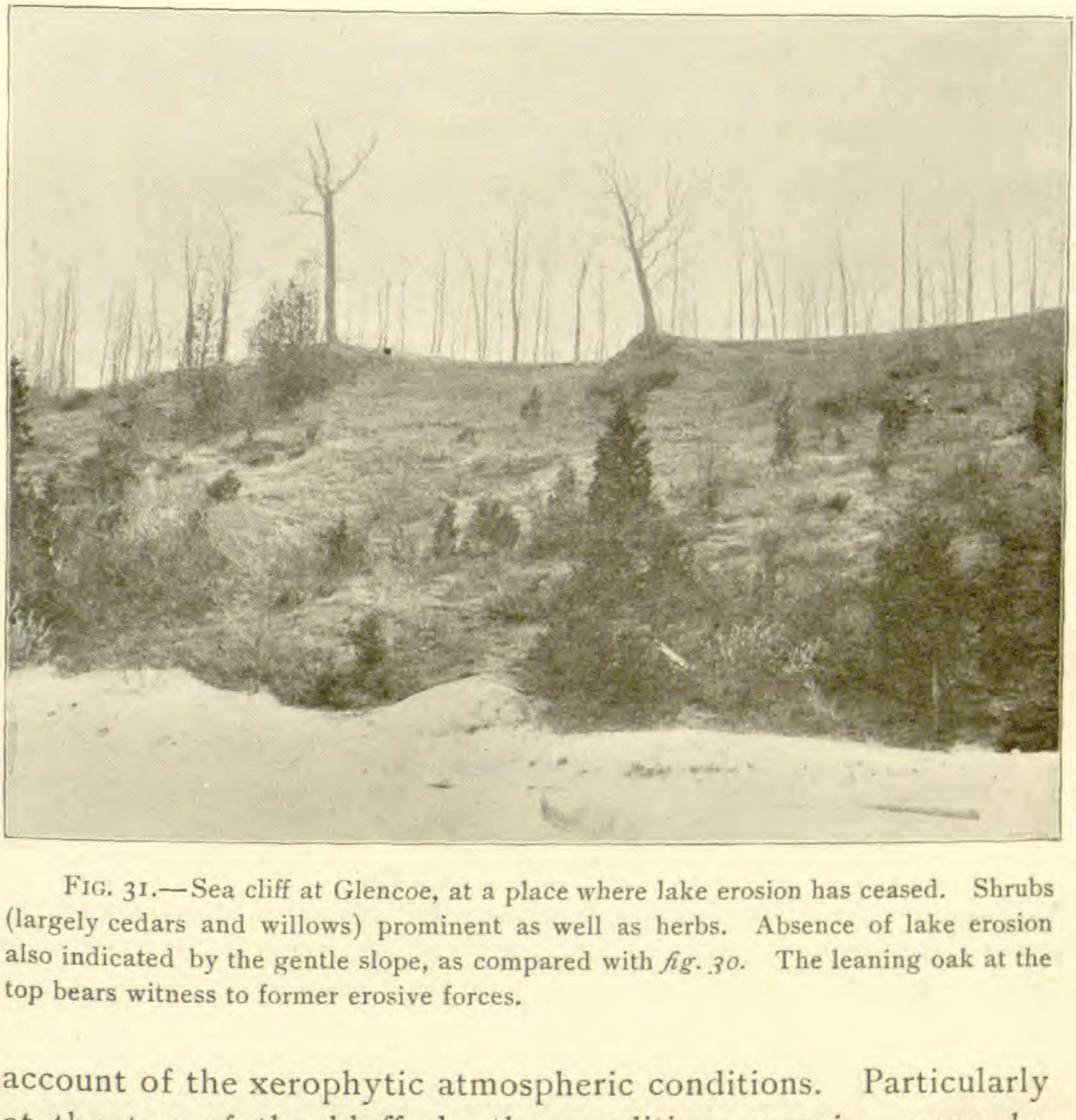

FIG. 31.—Sea cliff at Glencoe, at a place where lake erosion has ceased. Shrubs (largely cedars and willows) prominent as well as herbs. Absence of lake erosion also indicated by the gentle slope, as compared with *fig. 30*. The leaning oak at the top bears witness to former erosive forces.

account of the xerophytic atmospheric conditions. Particularly at the top of the bluff do the conditions remain severe, by reason of the great exposure and also the dryness of the soil. If the lake should recede for some distance, a mesophytic forest could certainly develop on the bluff before it is reduced to anything like the common level. This is shown on the ancient lake bluff at Beverly hills. Here there is an old cliff about forty

feet above the country level, representing a lake bluff of the Glenwood stage of Lake Chicago.[24] This bluff has long had a mesophytic forest on its slopes, and yet it will be many centuries before the erosive forces remove all traces of this ancient sea

FIG. 32.—Sea cliff at Glencoe, where lake erosion has been absent for a long period. Xerophytic trees and shrubs, especially conifers, dominate, *e. g.*, white pine, red cedar, juniper.

cliff. A still more striking case is to be seen north of Waukegan, where an ancient lake bluff, higher than that at Beverly hills and only a mile back of the present lake shore is tenanted by a high grade type of mesophytic forest.

It will be instructive to make a few comparisons between lake bluffs and other plant societies. Closest to the lake bluff in a

[24] SALISBURY and ALDEN: The geography of Chicago and its environs. Chicago, 1899.

physiographic sense is the river bluff. When a stream has banks of clay the conditions seem decidedly similar and yet the flora is not the same. A comparison of the lake bluffs at Glencoe with the bluffs along Thorn creek shows that some species are common, notoriously Ostrya, Rhus, Quercus, Populus. Yet the differences are still more striking, for the bluffs along Thorn creek do not show *Salix glaucophylla* nor Shepherdia; most striking of all, however, is the entire absence of conifers. When we compare the lake bluffs with the rock bluffs of the Illinois river we find that the resemblances are greater than the differences, since the river bluffs have conifers, though even here some of the lake bluff forms are absent. When, however, we compare the Glencoe bluffs with the dunes, we find that all of the dominant shrubs and trees of the bluff are found also on the dunes ; not only this, the dominant bluff forms are dominant on the dunes also.

The facts of the preceding paragraph are pregnant with significance. One obvious corollary is that given similar soils but dissimilar conditions of atmospheric exposure, as at Glencoe and Thorn creek, the vegetation is unlike. Another and more striking corollary is that given the most dissimilar soils possible, viz., the Glencoe clay and the dune sand, we still have similar vegetation, because the atmospheric conditions are the same in the two cases. The evidence of the Illinois river bluffs is less clear; they are more xerophytic than the bluffs along Thorn creek, but whether this is chiefly due to rock as against clay or to greater exposure is not certain. At all events these facts show that it is not enough to know about chemical or physical conditions in the soil. We cannot divide plants into those of clay, rock, and sand, but must take into account that most plants have a wide range of life so far as soil is concerned, provided the atmospheric conditions are congenial. The chief exception to this statement seems to be found not in the original soils but in the superimposed humus. There are many plants that require humus for their occurrence in nature, but it makes no difference whether the subsoil is rock, sand, or clay, provided alone that

the humus is present in sufficient quantity. It is by reason of this last fact that the mesophytic forest can appear in all conditions in this climate, since the mesophytic forest is associated to a high degree with humus.

2. THE BEACH-DUNE-SANDHILL SERIES.

A. *The beach.*—The author has previously discussed in considerable detail the dynamics of the dune societies,[25] and it will not be necessary to do more here than to summarize the chief conclusions, and add a few new data. Before long it is expected that a paper will appear giving the changes that have taken place since the first observations were made in 1896.

The beach in the Chicago area is xerophytic throughout. There is nothing analogous to the salt marshes of the Atlantic coast, nor to the hydrophytic shores farther north along Lake Michigan. The lower portion of the beach is exposed to alternate washing by the waves and desiccation in the sun, and is devoid of life. The middle beach, which is washed by winter waves, though not by those of summer, has in consequence a vegetation of xerophytic annuals, the most prominent of which is *Cakile Americana*. The upper beach is beyond present wave action, and is tenanted by biennials and perennials in addition to the annuals. *Fig. 33* shows a beach of this type, the lower beach being smooth and even, the middle beach covered with débris, while the upper beach has a scattered perennial vegetation.

The beach at the base of cliffs shows similar subdivisions, though the zones are much narrower as a rule. The vegetation, too, is much the same, though some forms, as Strophostyles, have not been seen as yet on the beaches of the dune district. At the foot of cliffs there often occur alluvial fans of sand, which have been deposited by the torrents during and following rain storms. These fans have a comparatively rich vegetation and species sometimes occur here that are not found elsewhere on the beach.

[25] COWLES, H. C.: The ecological relations of the vegetation on the sand dunes of Lake Michigan. BOT. GAZ. **27**: 95–117, 167–202, 281–308, 361–391. 1899.

B. *The embryonic or stationary beach dunes.*—Wherever plants occur on a beach that is swept by sand-laden winds, deposition of sand must take place, since the plants offer obstacles to the progress of the wind. If these plants are extreme xerophytes and are able to endure covering or uncovering without injury, they may cause the formation of beach dunes. Among the

FIG. 33.—Beach at Dune park, showing the smooth and naked lower beach, the middle beach with its line ot débris, the upper beach with scattered shrubs, and the dunes.

dune-forming plants of this type are *Ammophila arundinacea*, *Salix glaucophylla* and *S. adenophylla*, *Prunus pumila*, and *Populus monilifera*. The shapes of these beach dunes vary with the characteristics of these dune-forming plants. Ammophila dunes are extensive but low, because of strong horizontal rhizome propagation. Prunus and Populus dunes are smaller but higher, because of the relative lack of horizontal propagation and the presence of great vertical growth capacity. Dunes are formed more slowly in protected places, and here the dune-forming species may be plants that are ill adapted to the severest beach conditions, such as the creeping juniper.

C. *The active or wandering dunes. The dune complex.*—The stationary embryonic dunes on the beach begin to wander as soon as the conditions become too severe for the dune-forming plants. The first result of this change is seen in the reshaping of the dune to correspond with the contour of a purely wind-made form. The rapidity of this process is largely determined by the success or failure of the dune-formers as dune-holders. The best dune-holders are Calamagrostis, Ammophila, and Prunus.

There are all gradations between a simple moving dune and a moving landscape; the latter may be called a dune-complex. The complex is a restless maze, advancing as a whole in one direction, but with individual portions advancing in all directions. It shows all stages of dune development and is forever changing. The windward slopes are gentle and are furrowed by the wind, as it sweeps along; the lee slopes are much steeper. The only plant that flourishes everywhere on the complex is the succulent annual, *Corispermum hyssopifolium*, although *Populus monilifera* is frequent. The scanty flora is not due to the lack of water in the soil, but to the instability of the soil and to the xerophytic air.

The influence of an encroaching dune upon a preexisting flora varies with the rate of advance, the height of the dune above the country on which it encroaches, and the nature of the vegetation. The burial of forests is a common phenomenon. The dominant forest trees in the path of advancing dunes are *Pinus Banksiana* and *Quercus coccinea tinctoria*. These trees are destroyed long before they are completely buried. The dead trees may be uncovered later, as the dune passes on beyond.

In the Dune park region there are a number of swamps upon which dunes are advancing. While most of the vegetation is destroyed at once, *Salix glaucophylla*, *S. adenophylla*, and *Cornus stolonifera* are able to adapt themselves to the new conditions, by elongating their stems and sending out roots from the buried portions. Thus hydrophytic shrubs are better able to meet the dune's advance successfully than any other plants. The water relations of these plants, however, are not rapidly altered in the new conditions. It may be, too, that these shrubs have

adapted themselves to an essentially xerophytic life through living in undrained swamps. Again it may be true that inhabitants of undrained swamps are better able to withstand a partial burial than are other plants.

Vegetation appears to be unable to capture a rapidly moving dune. While many plants can grow even on rapidly advancing slopes, they do not succeed in stopping the dune. The movement of a dune is checked chiefly by a decrease in the available wind energy, due to increasing distance from the lake or to barriers. A slowly advancing slope is soon captured by plants, because they have a power of vertical growth greater than the vertical component of advance. Vegetation commonly gets its first foothold at the base of lee slopes about the outer margin of the complex, because of soil moisture and protection from the wind. The plants tend to creep up the slopes by vegetative propagation. Antecedent and subsequent vegetation work together toward the common end. Where there is no antecedent vegetation, Ammophila and other herbs first appear, and then a dense shrub growth of Cornus, Salix, *Vitis cordifolia*, and *Prunus Virginiana.* Capture may also begin within the complex, especially in protected depressions, where *Salix longifolia* is often abundant.

D. *The established dunes.*—No order of succession in this entire region is so hard to decipher as is that of the established dunes. There are at least three types of these dunes so far as the vegetation is concerned, and it is not yet possible to figure out their relationships. The continuation of the conditions as outlined in the preceding paragraph results in a forest society on the lee slope, in which is found the basswood, together with a most remarkable collection of mesophytic trees, shrubs, and climbers, which have developed xerophytic structures. These dunes are evidently but recently established, as is shown by the absence of a vegetation carpet; furthermore the slopes are almost always steep.

Again, there are forest societies in which the pines dominate, either *Pinus Banksiana* or *P. Strobus.* These arise from a heath, composed in the main of Arctostaphylos and Juniperus. The

heath appears to originate on fossil beaches or on secondary embryonic dunes or other places where the danger of burial is not great. It will be noted that both the heath and the pine forest are dominated by evergreens. These societies commonly occur near the lake or on lakeward slopes, which are northern slopes as well. On these coniferous dune slopes there is to be found another notable collection of northern plants, resembling ecologically the peat bog plants already mentioned. Heaths and coniferous forests also occur on sterile barrens and in depressions where the conditions are unfavorable for deciduous forests. A slight change in the physical conditions may bring about the rejuvenation of the coniferous dunes, because of their exposed situation. This rejuvenation commonly begins by the formation of a wind sweep, and the vegetation on either hand is forced to succumb to sand-blast action and gravity.

A third type of established dune is that in which the oaks predominate, and especially *Quercus coccinea tinctoria*. The oak dunes are more common inland and on southern slopes. Probably the oaks follow the pines, but the evidence on which this is based is not voluminous. The pines certainly have a wider range of habitat than the oaks, occurring in wetter and in drier soil and also in more exposed situations. The mutual relations of the pines and oaks are certainly interesting and deserve some very careful study. Pine forests prevail on the north or lakeward slopes and oak forests on the south or inland slopes. With the pines are other northern evergreen forms, such as Arctostaphylos, while with the oaks are Opuntia, Euphorbia, and other more southern types. The density of the vegetation on the north side is also in contrast with the sparser and more open vegetation of the south side. The cause for this radical difference on the two slopes is doubtless complex, but it is obvious that the north slope has greater moisture, shade, and cold, and probably more wind. Which of these is the more important is not certain, but the presence of the northern species seems in favor of cold or wind as the chief factor.

There are a number of interesting sand hills and ridges at

some distance from the lake. Some of these are fifteen miles from the present lake shore, while others are found at various intervals nearer and nearer the lake. It has been found that these can be grouped for the most part into three series, representing three beach lines of Lake Chicago, as the glacial extension of Lake Michigan has been called. The upper and oldest

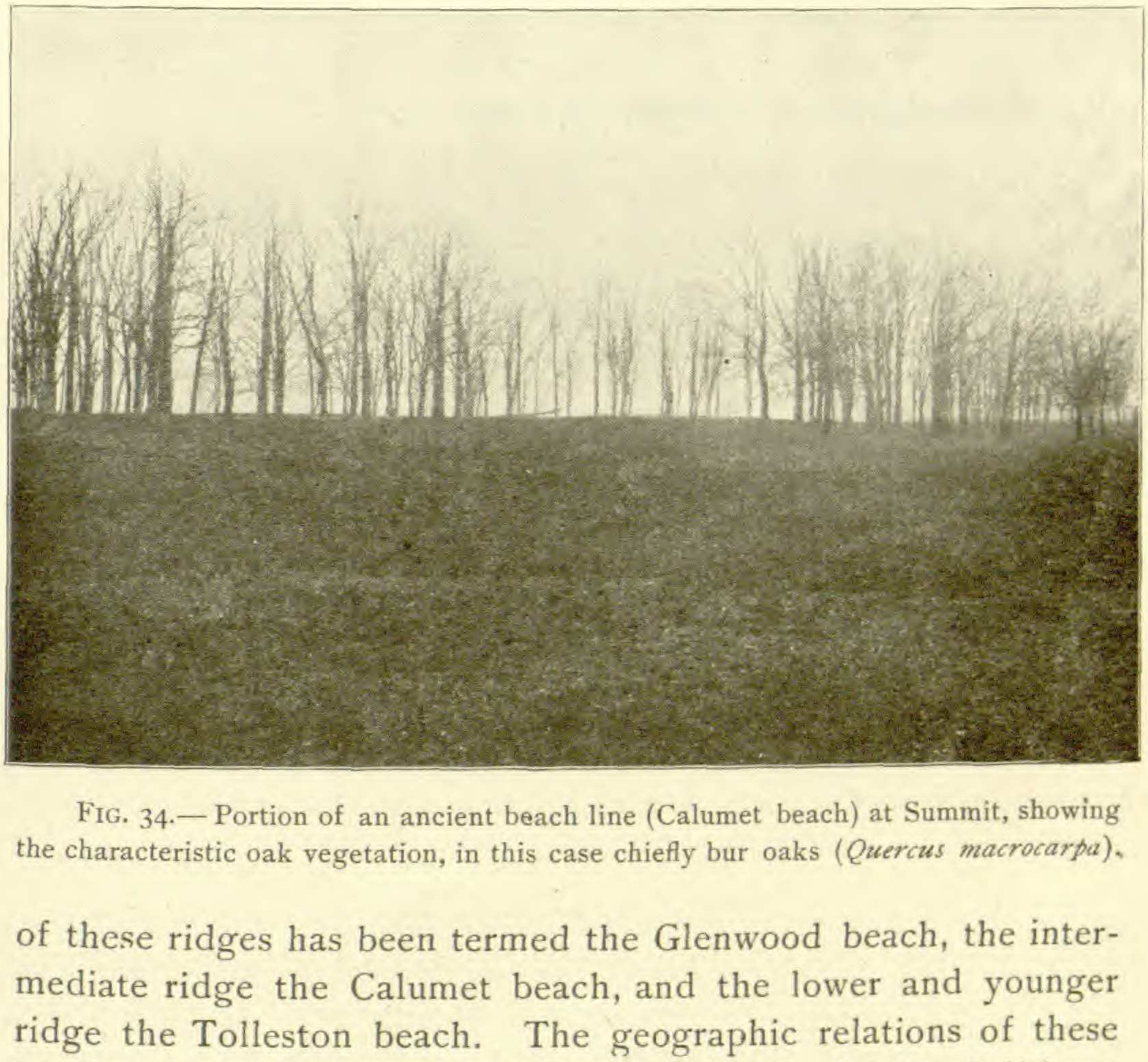

FIG. 34.— Portion of an ancient beach line (Calumet beach) at Summit, showing the characteristic oak vegetation, in this case chiefly bur oaks (*Quercus macrocarpa*).

of these ridges has been termed the Glenwood beach, the intermediate ridge the Calumet beach, and the lower and younger ridge the Tolleston beach. The geographic relations of these beaches is well discussed by Leverett[26] and also by Salisbury and Alden,[27] and nothing need be said here except as to the vegetation. In general these ridges and hills have a xerophytic forest flora, dominated by the bur, black, and white oaks (*Quercus macrocarpa, Q. coccinea tinctoria, Q. alba*). The proportions between these trees varies strikingly, though the bur or

[26] *Op. cit.* 55–85. [27] *Op. cit.* 31–51.

black oak is usually the chief character tree. No satisfactory reason can yet be given for these variations, though the bur oak appears to be more abundant on the lower and less drained ridges, while the black oak is more abundant on the higher ridges. The shrub undergrowth is commonly sparse, and the most frequent members of this stratum are the hazel (*Corylus*

FIG. 35.— Portion of an ancient beach (Glenwood beach) near Thornton. The trees here are chiefly black oaks (*Quercus coccinea tinctoria*); the beach is higher, and the trees more luxuriant than usual.

Americana), Rosa, the New Jersey tea (*Ceanothus Americanus*), *Salix humilis*, the low blueberry (*Vaccinium Pennsylvanicum*), and the huckleberry (*Gaylussacia resinosa*). Among the commoner herbs are *Silene stellata*, *Antennaria plantaginifolia*, *Heuchera hispida*, *Rumex Acetosella*, *Carex Pennsylvanica*, *Potentilla argentea*, *Poa compressa*, *Pteris aquilina*, *Ceratodon purpureus*. In open places there are often almost pure growths of Poa or Potentilla. *Figs. 34* and *35* show portions of these ancient beaches in which the oaks dominate; *fig. 34* shows, perhaps, the more common condition, *i. e.*, a rather low beach with a sparse tree growth.

The future of the vegetation on the established dunes and beaches is somewhat problematical. From analogy with other plant societies in this region, and from established dunes in Michigan, we should expect a mesophytic forest, probably of the white oak-red oak-hickory type at first and then followed by a beech-maple forest. There are evidences that some such changes are now taking place. On many of the oak dunes, especially where protected from exposure, there is already a considerable accumulation of humus. Herbaceous ravine mesophytes like Hepatica, Arisaema, and Trillium are already present, and with them mesophytic shrubs and trees, including the sugar maple itself, though the beech has not been found on the dunes of our area, as it has in Michigan. One might expect that the flora of the older Glenwood beach would have advanced more toward the mesophytic stage than has the flora of the younger Tolleston beach. Such, indeed, seems to be the case, especially at Glenwood, where the white oaks are more numerous, and the black oaks much larger and more luxuriant. The humus is richer and most things look as if the age of this beach were notably greater than that of the Calumet or Tolleston beaches. This subject, however, needs much further investigation. In any event, one character of the sand hill stands out in bold relief, viz., its great resistance to physiographic change. Not only is its erosion slower than that of the clay hill, but the advance of its vegetation is vastly slower at all points along the line. The slowness of humus accumulation accounts for this, perhaps, more than all else.

III. Summary and conclusion.

In the present paper the author has endeavored to show the need for a classification of plant societies which shall form a logical and connected whole. Warming's classification, based on the water content of the soil, is doubtless the best possible classification, if but one factor is used. Graebner's classification, based on soil characteristics, includes the advantages of Warming's scheme, and adds desirable new features.

The physiographic theory here presented is the result of several years of field study devoted chiefly to testing the current theories and to developing new ones. The classification is based on the fundamental notion that a true theory must be genetic and dynamic; the plant societies must be grouped according to origins and relationships, and the idea of constant change must be strongly emphasized.

The laws that govern changes in plant societies are mainly physiographic; whether we have broad flood plains, xerophytic hills, or undrained swamps depends on the past and present of the ever-changing topography. Nor is topographic change haphazard. Modern physiography has made a logical classification of dynamic surface forces, and has found a progressive tendency toward a definite end. Denudation of the uplands and deposition in the lowlands results in an ultimate planation, known as the base level. Wherever hills are being eroded, or lakes filled, or coastal plains enlarged, it is obvious that there must be changing plant societies, in other words, a definite order of succession of plant groups. These changes, too, are cumulative; a topographic form will have plants that are relicts of an older stage, as well as those that are typical of the new conditions, showing that the supplanting of one plant society by another is slow and gradual. The full effect of a given environment may not be felt till that environment has gone.

Using ecological terms in place of those of physiography, soil conditions tend to become more mesophytic as the base level develops. A young topography is rich in xerophytic hills and in hydrophytic lakes and swamps. There may be local retrogressions toward xerophytic or even hydrophytic plant societies, forming eddies, as it were, but the great movement is ever progressive and toward the mesophytic condition. Though instances of vast planation are found in geological history, the ultimate mesophytic base level is seldom reached, since crustal movements interfere with physiographic processes. So far as plants are concerned, however, a physiographic terminology may still be used, since all possible crustal changes are either toward or

away from the mesophytic, *i. e.*, progressive or retrogressive. Again, climatic changes doubtless occur; even here we may use the general terminology, since the new conditions either favor or retard the general mesophytic development. This leads to the general view that the climax type differs with the climate. While the general series of physiographic changes is much the same everywhere, the corresponding plant societies are vastly different. In a desert climate most of the societies, including the climax type itself, are xerophytic. Finally, there is at least one point where physiographic and ecological classifications must diverge. Changes in vegetation often take place where the topography remains the same; in other words, a cycle of vegetation may be shorter than a cycle of erosion. The following application of these principles applies only to the Chicago region.

The typical erosion series is based on the life history of rivers, and this series is the most instructive ecologically. An embryonic clay ravine is essentially a little desert, though this character is due more to the instability of the soil than to the ordinary xerophytic factors. Soon landslide action becomes much reduced, and a xerophytic flora may appear, though in a remarkably short time a rich mesophytic forest is developed. This forest is not permanent, but may be regarded as a temporary climax. Rock ravines, whether of limestone or sandstone, commonly have more vertical slopes and drip with moisture, favoring the growth of extreme shade plants. The stages in limestone and sandstone habitats are essentially the same in spite of great physical and chemical differences in the rock.

As a clay ravine widens, the exposure increases; xerophytic herbs appear at the top of the slope, and later farther down toward the stream bed. Xerophytic shrubs and finally xerophytic trees make their appearance, notoriously *Ostrya Virginica.* In the early stages of these xerophytic bluffs trees are often found that look back to the ravine for their origin, while under them are xerophytic herbs that are better suited to the new conditions. As the slopes of a mesophytic rock ravine pass to a xerophytic rock bluff, changes in the vegetation are most pronounced. A

slope less xerophytic than that of clay becomes more xerophytic as it becomes a river bluff, and conifers are found as well as deciduous xerophytes. As the bluff slopes become more gentle through erosive action, a mesophytic flora may gradually replace the xerophytes.

Before the growing valley possesses a permanent stream there may be developed in the torrent bed a vegetation of amphibious shade plants, and when the water becomes more permanent one may find algae and other hydrophytes. Spring brooks are infrequent, but they have a characteristic vegetation, due doubtless to the presence of more light and water. The development of a flood plain vegetation is well shown on river islands. First a sand bar develops, then an annual flora, and later a perennial vegetation in which Salix dominates. The river constantly erodes above and deposits below, hence the islands migrate down the stream, showing the oldest plant societies at the upper end. Depositing streams gradually develop a flood plain which shows an interesting succession of societies. Beyond the true hydrophytes there is commonly seen a Salix zone, then a zone of Populus and other trees on the older flood plain, and finally there develops a luxuriant mesophytic flood-plain forest which as a whole is permanent, though local retrogressions may occur. In some of these flood-plain forests there are found interesting southern types of trees. Occasionally meadows occur on flood plains in place of forests. Retrogressive processes are active on flood plains, such as terrace formation, which is due to further erosion; terrace development tends to favor xerophytes. New channels are also cut off, leaving portions of the old river as oxbow lakes; here hydrophytes of undrained swamps come in, and one often sees trees of the old river margin together with shrubs and herbs of the undrained swamps. These latter phases, however, are ephemeral and the mesophytic flood plain as a whole increases constantly in area.

The vegetation of undrained areas has a remarkably xerophytic stamp; this is possibly due to the unfavorable opportunity for root activity in undrained soils. In any event, these

areas are features of a young typography and they are soon filled up by accumulating peat. Algae and other hydrophytes characterize the lake or pond stages, and largely by their partial decay the water becomes shallow enough to support the vegetation of a marginal swamp, particularly rushes and sedges. After these forms there appear the most remarkable plant societies of the entire series, characterized chiefly by Cassandra and other ericads with xerophytic structures. Following the shrub stage there is the tree stage in which the tamarack often dominates, though pines appear later and ultimately mesophytes. In these swamps one finds the most perfect examples of the regular succession of plant societies, and hence of zonal arrangement. These peat bog societies contain a most striking collection of northern plants. There are various diverging types of undrained swamps, some with shallow soil and a vegetation without extreme xerophytic structures, others in which an imperfect drainage may account for the facts observed. The marginal vegetation is the same in all cases and is remarkably characteristic; this flora is sometimes seen after the lake and swamp floras have gone. Half-drained areas are characterized by luxuriance of the vegetation in the lake stage. The lake is followed in order by the bulrush, sedge, and grass stages, the latter being denominated the prairie stage. Whether this latter type passes into the forest is not certain; in any event, this mesophytic stage is not final, for the region must subsequently pass through the stages of the river series.

Uplands, as well as swamps, have an interesting history before they are attacked by stream erosion. Limestone hills and outcrops show first a lichen vegetation, followed by mosses and crevice herbs and later by shrubs and trees. The stages on clay hills pass far more rapidly, indeed early stages are hard to detect, and one almost uniformly finds a mesophytic forest of oaks and hickories in these habitats. Where the forest conditions are disturbed, there is a rapid return through a series of herb and shrub stages to the same tree types. It is somewhat probable that the oaks will be followed by sugar

maples and beeches, and this change is now occurring in some places. The mesophytic stage here also is not permanent, though it may endure for a long period.

Clay bluffs along an eroding coast are subject to considerable change involving the rapid destruction of upland vegetations. The changes, too, are so rapid that practically no vegetation can develop on the bluff slopes. If the erosive activity of the lake ceases, there soon appears a vegetation of xerophytic herbs, followed by xerophytic shrubs and trees in which conifers play a large part. There is a notable resemblance between the flora of the clay bluff along the lake shores and the flora of the sand dunes, and also the flora of rock bluffs along rivers, while the resemblance is less close to the flora of clay bluffs along rivers, showing that soil conditions may often be less important than conditions of aerial exposure.

The dune vegetation, presented in detail elsewhere, is summarized in this present paper. Nothing need be said in the way of further summary except to remark that dunes, like all other topographic forms in our climate, may ultimately develop a mesophytic forest, though the stages are far slower than in most of the other series.

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